

August 27, 2003



# Logistics

## Condition Based Maintenance-Plus (D-2003-125)

Department of Defense  
Office of the Inspector General

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### **Acronyms**

ADIP	Army Diagnostic Improvement Program
CBM <sup>+</sup>	Condition Based Maintenance-Plus
ICAS	Integrated Condition Assessment System
IMD-HUMS	Integrated Mechanical Diagnostic Health and Usage Monitoring System
LMI	Logistics Management Institute
OSD	Office of the Secretary of Defense
RCM	Reliability Centered Maintenance
SIM	Serialized Item Management



INSPECTOR GENERAL  
DEPARTMENT OF DEFENSE  
400 ARMY NAVY DRIVE  
ARLINGTON, VIRGINIA 22202-4704

August 27, 2003

MEMORANDUM FOR DEPUTY UNDER SECRETARY OF DEFENSE (LOGISTICS  
AND MATERIEL READINESS)

SUBJECT: Report on Condition Based Maintenance-Plus (Report No. D-2003-125)

We are providing this draft report for your information and use. No written response to this report was required, and none was received. Therefore, we are publishing this report in final form.

We appreciate the courtesies extended to the staff. Questions should be directed to Mr. Dennis E. Payne at (703) 604-8907 (DSN 664-8907) or Mr. Bernard M. Baranosky at (703) 604-8785 (DSN 664-8785). See Appendix C for the report distribution. The team members are listed inside the back cover.

By direction of the Deputy Inspector General for Auditing:

A handwritten signature in black ink that reads "Shelton Young".

Shelton R. Young  
Director, Readiness and  
Logistics Support Directorate

## Office of the Inspector General of the Department of Defense

**Report No. D-2003-125**

(Project No. D2003LH-0025)

**August 27, 2003**

### Condition Based Maintenance-Plus

#### Executive Summary

**Who Should Read This Report and Why?** Civil service and uniformed officers who are involved in major weapon system procurement or maintenance should read this report. The report discusses the DoD plan for incorporating embedded diagnostic equipment and sensors into new weapon systems and, where cost-effective, legacy weapon systems in order to reduce the maintenance costs and thereby reduce total DoD ownership costs.

**Background.** This audit was initiated to determine whether DoD was still achieving the maintenance savings from reliability centered maintenance that were identified in Inspector General of the Department of Defense Report No. 91-098, "Aircraft Depot Maintenance Programs," June 17, 1991. During the survey phase of this audit, we found that DoD was implementing a new maintenance concept (condition based maintenance-plus) that focuses on the actual condition of the weapon system and its components when determining maintenance requirements as opposed to time-phased or preventive maintenance procedures. Condition based maintenance-plus is one of the six initiatives of the Future Logistics Enterprise that is being implemented under the direction of the Deputy Under Secretary of Defense (Logistics and Materiel Readiness). The objective of the Future Logistics Enterprise is to provide integrated end-to-end logistical support.

**Results.** DoD was in the process of implementing a maintenance concept called condition based maintenance-plus. Maintenance requirements under condition based maintenance-plus are driven by the need to repair or replace the components based on the actual condition of the component as diagnosed by embedded sensors or external diagnostic equipment. DoD has developed a time-phased plan to implement the condition based maintenance-plus initiative. The plan is to evaluate incorporating condition based maintenance-plus technology into new weapon systems, and legacy systems, where cost-effective. The procedures and schedules contained in the implementation plan appear reasonable. Although the implementation process was in the early stages, and we could not formulate any conclusions on the effectiveness of the program, continued management emphasis and oversight will be needed to ensure the condition base maintenance-plus initiative is effectively implemented as planned within the Military Departments.

**Management Comments.** We provided a draft of this report on August 5, 2003. No written response to this report was required, and none was received. Therefore, we are publishing this report in final form.

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## Background

Maintenance accounts for a major portion of the total ownership costs of weapon systems within DoD. DoD estimated that it spends in excess of \$15 billion annually on depot maintenance. In the mid-1970s, DoD implemented Reliability Centered Maintenance (RCM) to increase the reliability and operational readiness of its weapon systems and reduce maintenance costs. RCM was originated by the Air Transport Association in the late 1960s, and has since been implemented by the airline industry.

**Reliability Centered Maintenance.** RCM is defined as a process used to determine what actions must be taken to ensure that a physical asset continues to do what its users want it to do in the environment that it was intended to operate. To accomplish that goal, RCM uses a logical and disciplined analytical procedure to identify what may cause an asset to fail to operate, and what adverse consequence that failure would have on areas such as business operations, personnel safety, and environmental protection. Based on the results of the analysis, a plan of action is developed that could result in a new or revised maintenance procedure, inspection, or, in the most severe case, an equipment redesign.

In the mid-1970s, the Office of the Secretary of Defense (OSD) established a requirement for the Military Departments to use the RCM process to determine preventive maintenance for both new and fielded systems. DoD issued its first formal guidance regarding RCM in August 1984.

**RCM Guidance.** DoD Directive 4151.16, “DoD Equipment Maintenance Program,” August 23, 1984, stated that RCM would be used as the basis for establishing and sustaining preventive maintenance programs for all DoD equipment. The directive also required the Military Departments to use RCM to justify new or modified maintenance tasks and to continually evaluate existing tasks. DoD Directive 4151.18, “Maintenance of Military Materiel,” August 12, 1992, replaced DoD Directive 4151.16 and deleted the requirement for the Military Departments to use RCM analyses.

**Military Department Guidance on RCM.** The Military Departments’ regulations still require that RCM analyses be updated on operational systems. However, since DoD Directive 4151.16 was replaced, the Military Departments placed less emphasis on RCM analyses. In addition, General Accounting Office Report No. GAO/NSIAD-93-163, “Depot Maintenance: Requirement to Update Maintenance Analyses Should Be Modified,” June 22, 1993, states that officials within the Military Departments believed that performing or updating RCM analyses on operational systems with extensive maintenance histories was not cost-effective because the analyses are expensive to perform and would not

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significantly reduce maintenance requirements. The report further states that officials from the Air Transport Association and the Federal Aviation Administration supported the position that RCM was not cost-effective. Many of the weapon systems within the DoD inventory fall into the category of mature systems with extensive maintenance histories.

**The Future Logistics Enterprise.** The Deputy Under Secretary of Defense (Logistics and Materiel Readiness) is implementing the Future Logistics Enterprise to achieve end-to-end customer service within DoD logistics operations. The Future Logistics Enterprise, which began in September 2001, comprises the following six initiatives.

- **Condition Based Maintenance-Plus (CBM<sup>+</sup>).** CBM<sup>+</sup> is a broad-based maintenance concept intended to predict equipment failures based on real-time or near real-time assessment of equipment condition obtained from embedded sensors and external tests and measurements using portable equipment. The intent of CBM<sup>+</sup> is to reduce maintenance down time and increase operational readiness by repairing or replacing system components based on the actual condition of the component as opposed to other maintenance concepts, such as scheduled or time-phased maintenance procedures.
- **Depot Maintenance Partnerships.** The primary intent of depot maintenance partnerships is to enhance depot support by enabling DoD depots to develop appropriate partnerships with the commercial sector, while recognizing the legitimate national security need for DoD to retain depot maintenance capability.
- **Total Life Cycle Systems Management.** The Total Life Cycle Systems Management initiative calls for program managers to be responsible for the overall management of the weapon system life cycle, to include acquisition, meeting of performance requirements, integration into the force, and sustainment throughout the system's life cycle.
- **End-to-End Distribution.** The objective of this initiative is to influence acquisition, sourcing, positioning, and transportation of materiel to its end user, ensuring that deployment and sustainment are synchronized.
- **Executive Agents.** Without clear and quantified requirements, the assigned Executive Agent cannot adequately plan to provide the needed support. This initiative is aimed at improving support to the warfighters by ensuring that the Executive Agent roles, responsibilities, resources, and capabilities are responsive to the

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supported Unified Command's deployment and sustainment requirements.

- Enterprise Integration. This initiative builds on efforts underway within the Services and the Defense Logistics Agency that successfully use commercial off-the-shelf tools for modern, integrated solutions to complex information requirements across the DoD logistics enterprise.

## Objectives

Our overall audit objective was to evaluate the implementation and sustainment of the Military Departments' maintenance programs designed to reduce aircraft depot maintenance costs and to review the management control program applicable to the audit objectives. We did not complete the objective on the management control program because the plans for implementing CBM<sup>+</sup> had not been completed and a management control program had not been developed. See Appendix A for a discussion of the audit scope and methodology.

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## Implementation of Condition Based Maintenance-Plus Within DoD

DoD was in the process of implementing a maintenance concept called CBM<sup>+</sup>. Maintenance requirements under CBM<sup>+</sup> are driven by the need to repair or replace the components based on the actual condition of the component as diagnosed by embedded sensors or external diagnostic equipment. The CBM<sup>+</sup> maintenance concept contrasts with traditional maintenance procedures, which primarily rely on time-phased (scheduled) maintenance, preventive maintenance, or “run to failure.” DoD has developed a time-phased plan to implement the CBM<sup>+</sup> initiative. The procedures and schedules contained in the implementation plan appear reasonable. Although the implementation process was in the early stages, and we could not formulate any conclusions on the effectiveness of the program, continued management emphasis and oversight will be needed to ensure the CBM<sup>+</sup> initiative is effectively implemented as planned within the Military Departments.

### CBM<sup>+</sup> Concept

CBM<sup>+</sup> is a broad-based maintenance concept that focuses on real-time or near real-time assessment of equipment condition obtained from embedded sensors and external tests and measurements using portable equipment. CBM<sup>+</sup> contrasts with reactive (run to failure) and preventive maintenance (scheduled) concepts. The CBM<sup>+</sup> concept includes any maintenance procedure or initiative that identifies maintenance requirements based on the actual condition of the weapon system.

**Application.** The CBM<sup>+</sup> concept is to evaluate and incorporate CBM<sup>+</sup> technologies into new weapon system acquisitions, such as the Joint Strike Fighter Program, which is developing the Prognostic and Health Management System for incorporation into Joint Strike Fighter aircraft. The CBM<sup>+</sup> initiative will also evaluate incorporating CBM<sup>+</sup> technologies into legacy systems where it is cost-effective. For example, the Integrated Mechanical Diagnostic Health and Usage Monitoring System was being installed on the Navy SH-60 and the Marine Corps CH-53 helicopters and was being tested by the Army for use on the UH-60 helicopter. Other systems and initiatives already in use that will be part of the CBM<sup>+</sup> initiative include Serialized Item Management, the Army Diagnostic Improvement Program, and the Navy Integrated Condition Assessment System. See Appendix B for brief descriptions of those initiatives.

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**Logistics Management Institute Study.** In August 2000, the Logistics Management Institute (LMI) issued a report on the results of their assessment of condition based maintenance\* in the Department of Defense. The assessment included a review of four initiatives that were either ongoing or under development and would be included in the CBM<sup>+</sup> maintenance concept. In addition to the four initiatives included in the assessment, the LMI report noted that the Military Departments were testing a number of programs that employed condition based maintenance technologies. Several of those programs were at various stages of actual development and evaluation. The LMI study concluded that condition based maintenance has the potential to increase operational readiness and mission reliability, as well as prevent unnecessary maintenance. The study's recommendations included increasing Service awareness of condition based maintenance concepts, improving coordination of individual Service initiatives, and issuing policy guidance on condition based maintenance.

## **CBM<sup>+</sup> Guidance and Oversight**

DoD will provide the overall policy and guidance to establish the framework and authority to facilitate the implementation of CBM<sup>+</sup> within DoD. The Maintenance Technology Senior Steering Group will be responsible to oversee the implementation of CBM<sup>+</sup> initiatives. The Services will be responsible for the development and implementation of their individual CBM<sup>+</sup> plans and initiatives.

**CBM<sup>+</sup> Policy.** In November 2002, Deputy Under Secretary of Defense (Logistics and Materiel Readiness) issued an interim policy memorandum on CBM<sup>+</sup> implementation. The policy states that all Major Defense Acquisition Programs will consider CBM<sup>+</sup> technologies as system performance requirements during the design and development phase and throughout the life cycle of the acquisition. The policy states that incorporation of CBM<sup>+</sup> into legacy weapon systems would be based on the results of a cost benefit review for each legacy system that is a candidate for CBM<sup>+</sup> technology. The interim policy also defines the specific objectives anticipated to be achieved by implementing CBM<sup>+</sup> and tasks the Maintenance Technology Senior Steering Group with monitoring CBM<sup>+</sup> implementation. The Steering Group is chaired by the Assistant Deputy Under Secretary of Defense (Maintenance Policy, Programs and Resources) and consists of senior logistics representatives from the Services; representatives from the Offices of the Secretary of Defense that deal with logistics technology; and the Director, Joint Depot Maintenance Activities Group. The overall mission of the Steering Group is to provide visibility and assist in the coordination of the

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\* The LMI study discussed in this paragraph addresses condition based maintenance. The rest of this report uses the DoD term, Condition Based Maintenance-Plus (CBM<sup>+</sup>), which is the program DoD is in the process of implementing.

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logistics technology initiatives of the Military Services, the Defense Logistics Agency, and the Joint Staff.

**Maintenance Technology Senior Steering Group.** In addition to having oversight responsibility for CBM<sup>+</sup> initiatives, the Maintenance Technology Senior Steering Group will provide a forum for the exchange of information about CBM<sup>+</sup> to ensure that all CBM<sup>+</sup> efforts within DoD are appropriately coordinated and synchronized. The Steering Group also has the responsibility to manage the CBM<sup>+</sup> Advisory Group that it chartered to assist with CBM<sup>+</sup> implementation throughout the DoD acquisition, logistics, and maintenance processes. The Advisory Group consists of representatives from the Office of the Assistant Deputy Under Secretary of Defense (Maintenance Policy, Programs and Resources), the Army, Navy, the Air Force, the Marine Corps, the Joint Staff, and the Defense Logistics Agency. The representative from the Office of the Assistant Deputy Under Secretary of Defense (Maintenance Policy, Programs and Resources) chairs the Advisory Group and, together with the chair of the Maintenance Technology Senior Steering Group, is responsible for updating the Deputy Under Secretary of Defense (Logistics and Materiel Readiness) on CBM<sup>+</sup> progress and issues.

**CBM<sup>+</sup> Advisory Group.** The mission of the Advisory Group is to assist in CBM<sup>+</sup> implementation throughout the Department's logistical and maintenance operations. To accomplish its mission, the Advisory Group's charter states that it will be responsible for accomplishing the following objectives.

- Prepare draft OSD policy on CBM<sup>+</sup> and routinely revise the policy as necessary.
- Provide guidance and recommendations to the Services during their development of the individual Service CBM<sup>+</sup> plans.
- Establish an active clearinghouse for CBM<sup>+</sup> information for the use of the Services.
- Monitor and coordinate CBM<sup>+</sup> efforts throughout DoD.
- Advise the Maintenance Technology Senior Steering Group and others on CBM<sup>+</sup> issues.

At a minimum, the Advisory Group will meet within 2 to 3 weeks before the quarterly meetings of the Maintenance Technology Senior Steering Group. Additional meetings will be scheduled as deemed necessary.

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## CBM<sup>+</sup> Implementation Plan

To accomplish the CBM<sup>+</sup> objectives, an action plan was developed by the Office of the Assistant Deputy Under Secretary of Defense (Maintenance Plans, Programs and Resources). The plan is divided into five major areas and lists specific actions that must be completed for each area.

**Establishing the Framework.** This area primarily involves developing and publishing top-level policy. The actions required to complete this area of the plan follow.

- Incorporate CBM<sup>+</sup> direction into the 4000 and 5000 series guidance (will be done as required).
- Issue interim DoD policy (completed, November 2002).
- Services establish CBM<sup>+</sup> implementation plans (January 2004).

**Changing the Environment.** Actions under this area focus on changing the maintenance environment by encouraging CBM<sup>+</sup> initiatives and assisting in implementing technological improvements. The first step will be to identify what CBM<sup>+</sup> initiatives are available and evaluate the level of success for each initiative. To identify and evaluate the success of CBM<sup>+</sup> initiatives, a survey will be conducted and input solicited from within the Services as well as from the private sector. To accomplish the objectives of this area of the plan, the following actions must be completed.

- Catalog and characterize the most beneficial maintenance technologies and processes (October 2003).
- Conduct surveys of specific programs and activities (October 2003).
- Compile survey results (January 2004).
- Develop an outline to establish the DoD CBM<sup>+</sup> baseline (April 2004).

**Synchronize Initiatives.** Many of the objectives of CBM<sup>+</sup> can be accomplished by similar maintenance techniques and technologies. Therefore, it is imperative that there is adequate coordination within and among the Services to eliminate duplication of effort and increase commonality to the greatest extent possible. A centralized CBM<sup>+</sup> repository, containing information on various successful and unsuccessful CBM<sup>+</sup> initiatives, will assist program managers in selecting those initiatives that have the highest potential for successful implementation. A centralized repository can also promote the use of the same technology for

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different weapon systems. To effectively implement the objectives of this area of the plan, the following actions need to be accomplished.

- Develop an accessible central repository for CBM<sup>+</sup> information (July 2003).
- Obtain and include valid, current information in the central repository (as available).
- Develop a strategy to assess Service CBM<sup>+</sup> plans (April 2004).
- Provide a roadmap for CBM<sup>+</sup> initiatives (May 2004).

**Investment Justification.** Actions under this area will concentrate on assisting program managers in investing in CBM<sup>+</sup> initiatives. As with any budgetary request, justification must be provided during the budgetary process. Implementing CBM<sup>+</sup> initiatives often requires an investment in hardware, software, design, engineering, and analysis, which can present a formidable challenge in obtaining the required funding. Completing the following actions will assist program management offices in overcoming the challenge of investment justification.

- Review programs with CBM<sup>+</sup> initiatives for business case analysis (April 2004).
- Review programs with CBM<sup>+</sup> initiatives for documented operational readiness impact studies (April 2004).

**Managing for Success.** This area deals with establishing oversight mechanisms for CBM<sup>+</sup> implementation and progress review. Establishing a disciplined progress review process will ensure new personnel become aware of CBM<sup>+</sup> and that available CBM<sup>+</sup> technologies are incorporated into new weapon systems to the extent possible so that CBM<sup>+</sup> implementation stays on track. To ensure continued success of CBM<sup>+</sup> implementation, the following actions need to be accomplished.

- Assign oversight responsibilities to the Maintenance Technology Senior Steering Group (completed).
- Establish a CBM<sup>+</sup> Advisory Group (completed).
- Review the individual Service CBM<sup>+</sup> plans (March 2004).
- Report on the status of CBM<sup>+</sup> initiatives annually and respond to taskings from the Steering Group (ongoing).

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## Conclusion

CBM<sup>+</sup> is one of six initiatives that DoD is implementing to streamline logistics and provide the customer with end-to-end service. CBM<sup>+</sup> has the potential to decrease the cost of maintenance and, at the same time, to increase the operational readiness of the system. By employing the CBM<sup>+</sup> concept, which is driven by need as opposed to time-phased maintenance procedures, unnecessary maintenance efforts can be reduced, thereby reducing the total cost of weapon system support. As of March 2003, DoD had a time-phased plan of action for implementing the CBM<sup>+</sup> initiative. However, the implementation process was in the early stages and, as a result, quantitative data was not available to evaluate the effectiveness of the program at the time of this audit. As with any initiative that involves cross-Service implementation, continued management emphasis and oversight will be needed to ensure that the implementation of the CBM<sup>+</sup> initiative continues as planned.

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## Appendix A. Scope and Methodology

We reviewed policies, procedures, processes, and guidance regarding DoD depot maintenance that were applicable to the audit objective. We also reviewed the CBM<sup>+</sup> implementation plan, briefings, studies, and other documentation applicable to the CBM<sup>+</sup> initiative. The information reviewed covered a period from August 2000 through March 2003. We met with personnel from the Office of the Assistant Deputy Under Secretary of Defense (Maintenance Policy, Programs and Resources); the Office of the Army Deputy Chief of Staff for Logistics; the Army Aviation and Missile Command; the Army Materiel Command; the Naval Air Systems Command; and the Office of the Air Force Deputy Chief of Staff for Installations and Logistics.

We performed this audit from December 2002 through July 2003 in accordance with generally accepted government auditing standards. The initial survey work focused on determining how effectively the Services had implemented RCM at aircraft maintenance depots and that work was performed at Tinker Air Force Base in Oklahoma City, Oklahoma; Naval Air Depot Cherry Point in Cherry Point, North Carolina; Naval Air Systems Command, Patuxent River, Maryland; and Redstone Arsenal Army Depot, Huntsville, Alabama.

During the survey phase of this audit, we found that DoD was implementing a new maintenance concept called CBM<sup>+</sup> and our audit effort was refocused to concentrate on the implementation of CBM<sup>+</sup>. The CBM<sup>+</sup> concept, as planned, will be applicable to all weapon systems; therefore, this report does not specifically address aircraft depot maintenance, which was the announced title of the project.

**Computer-Processed Data.** Computer-processed data was not used in the performance of this audit.

**General Accounting Office High-Risk Area.** The General Accounting Office has identified several high-risk areas in DoD. This report provides coverage of the Improve the Quality of Logistics Support high-risk area.

### Prior Coverage

No prior coverage has been conducted on condition based maintenance during the last 5 years.

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## Appendix B. Selected Initiatives Under Condition Based Maintenance-Plus

### **Joint Strike Fighter Program – Prognostic and Health Management System.**

The Joint Strike Fighter is being developed as the next generation fighter aircraft for the Navy, the Air Force, the Marines Corps, and our allies. Included in the program is the Prognostic and Health Management System that will be incorporated into Joint Strike Fighter aircraft to enhance mission reliability and aircraft safety, as well as to reduce life-cycle support costs. The system is being developed to perform in-flight monitoring on the condition and performance of all major components and subsystems of the aircraft and transmit the data back to the aircraft's base or ship. That will provide the ground crew with real-time information on the aircraft and enable the ground crew to be prepared to perform whatever maintenance is required before the aircraft lands. That will reduce the aircraft's down time between sorties, thereby making the aircraft available to perform a greater number of sorties in a given period. The Prognostic Health and Monitoring System will reduce or eliminate the need for scheduled inspections and flight line trouble shooting. The system will also enhance flight safety by identifying potentially catastrophic failures before they occur.

### **Integrated Mechanical Diagnostic Health and Usage Monitoring System.**

The Integrated Mechanical Diagnostic Health and Usage Monitoring System (IMD-HUMS) was developed as a Commercial Operations and Support Savings Initiative program. IMD-HUMS automatically records, analyzes, communicates, and stores information about the operation, condition, and usage of helicopters and their major assemblies. IMD-HUMS is a complete information system optimized to serve civil and military users, original equipment manufacturers, and major subsystem and component suppliers. IMD-HUMS has been designed to support a variety of health and maintenance functions relating to helicopters, including Engine Performance Assessment, Rotor Track and Balance (RTB), Absorber Tuning, and Mechanical Diagnostics. The IMD-HUMS was being used on the SH-60 and CH-53 helicopters and was being evaluated by the Army for use on the UH-60 helicopter.

**Army Diagnostic Improvement Program.** The objective of the Army Diagnostic Improvement Program (ADIP) is to improve the diagnostics and prognostics of all Army weapon systems and equipment by the application of common technologies across multiple systems. The ADIP predictive maintenance concept originated in diesel-powered vehicles, including trucks, self-propelled artillery howitzers, the Bradley fighting vehicle, tank retrievers, bulldozers, construction equipment, and watercraft. The equipment scope of

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ADIP, particularly when Army gas turbine helicopters are added, is by far the largest and most diverse application within DoD of a single CBM<sup>+</sup> technology.

**Serialized Item Management.** Serialized Item Management (SIM) programs enable and encourage the effective management of populations of select items throughout their life cycles by marking the items in the population with a unique identification number and enabling the generation, collection, and analysis of maintenance data about each specific item. SIM programs will be primarily used on repairable items, including repairable components and subcomponents.

**Navy Integrated Condition Assessment System.** The Integrated Condition Assessment System (ICAS) is a data acquisition and analysis system comprising hardware, software, and sensors for monitoring equipment and scheduling maintenance based on equipment condition. ICAS presents a basic CBM<sup>+</sup> system, which performs condition monitoring of surface ship propulsion and hull, mechanical, and electrical subsystems and transmits condition data to a shipboard maintenance workstation network for trend analysis.

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## **Appendix C. Report Distribution**

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